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BEST MANAGEMENT PRACTICES (BMPs) for COOLING WATER SYSTEMS

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I. BACKGROUND

With proper operation and maintenance of cooling water systems (cooling systems) you can reduce the amount of toxic pollutants released into the Publicly Owned Treatment Works (POTW), while simultaneously lowering cooling system costs. Unless properly controlled, the air-water interaction in an evaporative cooling tower can produce a highly corrosive environment, which will corrode metal components, rapidly releasing copper and other metals into the waste stream. This corrosion of the metallic components reduces the operating life of the equipment, resulting in higher maintenance and replacement costs. Properly maintained and operated cooling systems will release lower concentrations of copper and other toxic metals into the sewer system. It is the responsibility of all cooling system users to properly operate their systems, and to minimize the metal contaminants in cooling system blowdown water.

The Best Management Practices (BMP) for cooling systems are intended to provide guidance as to which cooling system operation, maintenance, and procurement practices are likely to minimize the discharge of toxic metals into the POTW. Owners and operators of cooling systems are requested to:

1. Perform the simple diagnostic tests discussed in Section II, **COOLING SYSTEM DIAGNOSTICS,** and compare the results to indicator values given in Table 1. Systems that fail the diagnostic indicator tests should be further evaluated to determine if improvements to the equipment or to the operating practices could reduce the level of copper or zinc released in the blowdown water.

2. Conform to the procedures recommended in Section III, **PROCUREMENT PRACTICES,** when purchasing cooling systems, or replacement components.

3. Review operation and maintenance practices and compare them to the practices discussed in Section IV, **OPERATION AND MAINTENANCE PRACTICES.** Cooling system operations should be modified where possible to conform to the best management practices listed here, even if the system passes the indicator tests.

4. Take action today. Follow the steps in section V, **GETTING STARTED,** to

reduce the discharge of toxic metals to the POTW.

Cooling System Description

Cooling systems are used in air conditioning, heating (steam) and process cooling. Open recirculating cooling systems typically consist of an evaporative cooling tower, piping, and a heat exchanger. In air conditioning systems the heat exchanger is often called a chiller, while in steam systems the heat exchanger is often called a condenser. Closed recirculating cooling systems, often used in equipment cooling, usually transfer heat to an open recirculating system.

"Blowdown" is water, which is periodically discharged from the cooling system to remove contaminants that would otherwise continue to build up.

Sources of Copper and Zinc in Cooling Systems

Metals can get into cooling system water from corrosion of the materials used to construct the equipment (cooling tower, heat exchanger, and piping), or from the use of conditioning chemicals containing metals. Copper is a common material of construction in cooling systems. Because of its excellent heat transfer efficiency, heat exchangers, and condensers are often made from copper. Copper piping is also commonly found in cooling systems. The wood slats of many cooling towers are often impregnated with copper to preserve the wood.

Zinc is also common in cooling systems. Under corrosive conditions, the zinc is released from cooling towers made with galvanized steel structural members. Chemicals added to the cooling waters, especially corrosion inhibitors, can also contain zinc.

Corrosion breaks down and dissolves metal components when dissolved oxygen in the cooling water oxidizes the metal. Biological films, which grow rapidly in unprotected cooling systems, will accelerate corrosion and dissolving of the metal.

II. COOLING SYSTEM DIAGNOSTICS

Numerous diagnostic tests are available for evaluating the effectiveness of current operating practices. Table 1 presents a list of indicators for identifying possible cooling system operating problems. The tests for comparison with these indicators should be performed by a professional cooling system or water service company, or by a certified cooling system operating engineer or other industrial water treatment specialist.

Corrosion Rate Tests

Corrosion rate can be directly measured with corrosion coupons and corrosion rate meters. These devices are discussed in the section on **SYSTEM MONITORING AND MAINTENANCE.** They give the best indication of how well your corrosion protection program is functioning.

TABLE 1

COOLING SYSTEM DIAGNOSTIC INDICATORS

PROBLEM INDICATORS [1,2]	POSSIBLE PROBLEM	ACTIONS TO TAKE
CORROSION RATE: Copper > 0.2 mpy **CONCENTRATION IN COOLING WATER:** [3] Copper > 0.25 mg/l or Iron > 1.0 mg/l or Zinc > 0.5 mg/l	a. Excessive corrosion. b. Inadequate chemical dosage control. c. Use of conditioning chemicals containing copper or zinc.	a. Improve corrosion protection or use non-copper components. b. Improve chemical dosage control and/or monitoring. c. Eliminate use of chemicals containing copper of zinc.
CONCENTRATION IN COOLING WATER: Chlorine ^{3} 0.5 mg/l Chlorobromine ^{3} 0.5 mg/l Ozone ^{3} 0.2 mg/L	Over-dosing oxidizing chemical leads to excessive corrosion.	Reduce or stabilize dosage. Improve monitoring. Install automatic feed system
CONCENTRATION IN COOLING WATER: Carbon dioxide > 5 mg/l[4]	Copper oxide protection is inhibited.	Raise pH.
pH OF COOLING WATER: pH < 7.0	Inadequate pH control.	Check acid feed rate or implement pH control.
WATER VELOCITY IN COOLING WATER PIPING: > 3 feet/sec @ 150°F or above > 5 feet/sec @ 120°F > 8 feet/sec @ 90°F or below	Erosion of copper materials.	Reduce recirculation rate, increase line size, or replace copper elements with non-metallic parts.

1. The indicator levels presented in Table 1 are not intended for use in municipal ordinances, or other regulatory compliance statues, as limit levels which, when not complied with, would lead to enforcement action. These indicator levels should be considered guideline levels for cooling tower systems operating under normal conditions. It is intended that when cooling tower systems do not meet these levels, further investigation should be undertaken to determine if the operation of the cooling tower system can be modified to reduce the release of copper of zinc. On the other hand, unusual circumstances may be found which do not permit the system to be operated effectively within these guidelines.

2. These indicators are intended to assist in identifying cooling tower systems, which may have metals contamination problems, and to serve as goals for Best Management Practices. Passing these indicators does not guarantee that a system is free of pollutants. Testing for these indicators should be repeated monthly and supplemented with a complete system check by a qualified cooling tower service professional. Any suitable test method given in the latest edition of Standard Methods for the Examination of Water and Wastewater (published by the APHA, AWWA and WEF) may be used to test for the above indicators. Inexpensive hand-held colorimetric test kits are available for copper (0.1 mg/l increments) and iron (0.2 mg/l increments). Hand-held test kits are also available for zinc.

3. Indicator concentrations assume five to eight cycles of concentration.

4. Measured by titration method.

Cooling Water Chemical Tests

Chemical testing of cooling water can also evidence possible corrosion problems, and can give an indication of possible causes of excessive corrosion and/or metals in the cooling system blowdown. Cooling systems should be tested for:

1. Concentrations of:
   - Metals: Copper, iron, and zinc
   - Chlorine, chlorobromine, or ozone if added to the system
   - Carbon dioxide
2. pH
3. Water velocity in the piping

The results are usually more representative if the tests are repeated three times or more. The results of these tests should be compared to the guidelines contained in Table 1. If this comparison indicates that your system has excessive metal or carbon dioxide concentrations, low pH, of high water velocity, then your cooling system should be evaluated by a reputable cooling system service vendor or by a Certified Operating Engineer or industrial water treatment specialist. Identified problems or deficiencies, which may be contributing excessive metals to the waste stream, should be addressed and corrected.

Review of Cooling System Management Practices

Whether or not the cooling system is operating with diagnostic indicators within an acceptable range, a review of the operating, maintenance, and procurement practices should be preformed and compared to the guidelines presented in the following sections. Ways to modify these practices to further reduce discharge of metals to the sewer system may be identified.

III. PROCUREMENT PRACTICES

Alternative equipment materials and conditioning chemicals are available which do not contain toxic metals, especially copper, chromium and zinc. Your best opportunity for reducing or eliminating toxic metals in blowdown water, therefore, is during procurement.

Equipment Materials

Copper and zinc galvanized steel are common materials found in cooling systems. They are often a primary source of copper and zinc in blowdown water. Thus, the most effective and fail-safe method of reducing the concentration of these metals in blowdown water is to replace system components with materials that do not contain copper or zinc. Many non-metallic materials of construction are available, including fiberglass, PVC, plastics, ceramics, and wood. Other possibilities are stainless steel, anodized aluminum and metals with corrosion resistant coatings (except galvanizing).

Since they are less susceptible to corrosion, copper/nickel alloys including brass are preferred to pure copper.

When purchasing new cooling systems or replacing components in existing systems, make sure that non-metallic or non-corrosive materials (eg. stainless steel, anodized aluminum) are used in the equipment purchased. Also check that the new materials are compatible with, or isolated from, existing materials so as to avoid galvanic corrosion (eg. steel materials must be insulated from copper materials).

CHEMICAL FEED SYSTEM

The chemical feed system is a very important part of a cooling system. With a good chemical feed system, the problems of poor dosing control, such as high chemical costs from overfeeding, and corrosion of metals from overfeeding acids of oxidizing chemicals, are avoided.

CONDITIONING CHEMICALS

All conditioning chemicals purchased and used in the cooling system should be free of copper, chromium, or zinc.

SERVICE CONTRACT PROCUREMENT

Whenever possible, the guidelines in these BMPs should be written into service contracts for cooling systems. Examples would be prohibiting the use of chemical additives containing chromium, copper, or zinc; requiring that the copper corrosion rate not exceed 0.2 mpy; or requiring that the weekly and monthly monitoring activities mentioned in these BMPs (page 7) be conducted.

NON-RECIRCULATING COOLING SYSTEMS

The use of non-recirculating (also known as "single pass" and "once through") cooling systems is strongly discouraged as these systems use excessive amounts of water.

IV. OPERATION AND MAINTENANCE PRACTICES

This section discusses those operation and maintenance practices, which will assist in minimizing environmental pollution. As you read through these suggested practices, compare them to your current practices and modify your operations wherever possible to make the system "environment friendly".

CONDITIONING CHEMICALS

Water conditioning chemicals are used in cooling systems for control of corrosion, biological growth, and scale formation. Table 2 lists environmentally preferable conditioning chemicals.

TABLE 2

CONDITIONING CHEMICALS

CONDITIONING CHEMICAL	USAGE	MAXIMUM CONCENTRATION* IN COOLING WATER
Molydates	Inhibit corrosion	40 mg/l as molybdenum
Aromatic Triazoles	Inhibit corrosion	2 to 4 mg/l
Orthophosphates Polyphosphates	a. Inhibit corrosion b. Control scaling	20 mg/l as PO_4
Organophosphates (phosphonates)	Control scaling	20 mg/l as PO_4
Sodium silicate	Inhibit corrosion	100 mg/l as SiO_2
Non-oxidizing biocides: • Isothiazolin • Dinitrilopropionamide • Quarternary amines	Inhibit biological growth	
Chlorine	Inhibit biological growth	5 mg/l
Bromine, chlorobromine	Inhibit biological growth	1 mg/l
Ozone	Inhibit biological growth	0.2 mg/l

* If corrosion protection of the cooling system necessitates high chemical dosing rates which results in the concentration of inhibitors to exceed these recommended maximum levels, the system should be thoroughly investigated for the cause.

Corrosion Inhibitors

Control of corrosion is important in extending the life of equipment. It also limits the dissolution of environmentally toxic metals from copper and zinc galvanized components. Corrosion prevention systems should favor the use of environmentally acceptable chemicals such as the triazoles, molybdates, and ortho/polyphosphates listed in Table 2.

<u>Do not use corrosion inhibitors which contain chromium (dichromate) or zinc.</u>

Biological Growth Inhibitors

Biocides are used to inhibit the growth of algae and other organisms. Buildup of biological growths reduces heat transfer efficiency and increases corrosion. Biocides containing copper or other toxic heavy metals should not be used. Chlorine, bromine, chlorobromides, and ozone do not contain heavy metals. As these biocides can corrode metals if concentrations are too high, dosage rates must be carefully controlled. Various non-oxidizing organic compounds such as isothiasolin, dibromonitriloproprionamide (DBNPA), and quaternary amines are also available for inhibiting biological growth.

Scale Inhibitors

As with other conditioning chemicals, scale-inhibiting chemicals should not contain toxic compounds. Among the chemicals available for scale control are various phosphonates, orthophosphates, and polyphosphates.

SYSTEM MONITORING AND MAINTENANCE

Cooling systems, especially those with cooling towers, are subject to influences from many variables:

- Equipment failures
- Chemical feed rate drifting
- Seasonal weather changes
- Variations in makeup water or chemical additives
- etc.

Because of this propensity for changes, a regular maintenance program is essential to ensure the proper functioning of the system. The following maintenance program is suggested as a minimum, and should be adequate for most small and medium sized systems. Large cooling systems require more extensive monitoring.

Daily Record blowdown and makeup water flows. Significant variations in daily flow may give early warning to system malfunctions or changed conditions.

Weekly Check pH, temperature and conductivity. Significant variation from normal may indicate malfunctions or changed conditions requiring further investigation.

Monthly Have a qualified cooling system service vendor or certified operating engineer perform the following:

- Inspect the system, checking for proper equipment function and physical evidence of corrosion.
- Test the water quality of cooling system water for at least the following parameters:
  - Copper, iron, and zinc
  - pH

  Levels should be within the ranges specified in Table 1, Cooling System Diagnostic Indicators.
- Check corrosion rate, see Corrosion Monitoring below.

Careful attention to system requirements will indicate where additional monitoring may be necessary.

Corrosion Monitoring

All cooling systems should have a corrosion-monitoring program. Corrosion can be monitored using corrosion coupons, corrosion rate meters, or other monitoring devices. Corrosion is normally measured in terms of mils (thousandths of an inch per year (mpy).

Corrosion Coupons. One of the most effective ways to directly test cooling system water for corrosivity is to install copper, iron and zinc corrosion coupons in your cooling system. The coupons are strips of metal, which are placed in the cooling system to directly measure corrosion. Preweighed coupons are immersed in the cooling water for one to two months, then removed, reweighed, and visually inspected for corrosion and pitting. The measured loss of weight gives an indication of the average rate of corrosion over the one to two months time period. Corrosion coupons are available from cooling system and water service companies. They should be installed only be experienced persons since the type of metal in the coupon, water flowrate past the coupon, and other factors will influence the rate of corrosion. The type of metal in the coupon and the installation conditions should be matched as closely as possible to the conditions of the cooling system metal components.

Corrosion coupons have the advantages of being low cost and of being able to measure cumulative (average) corrosion loss. The disadvantages of coupons include not being able to measure corrosion at any instant, and not being able to tell how much the corrosivity of the water fluctuates.

Corrosion Rate Meters. Corrosion rate meters measure instantaneous corrosion rates. They can be either portable units or permanent installations. If the corrosion rate meter is hooked up to a continuous recording device, it can measure long-term corrosion rate in addition to the instantaneous rate. These devices have the capability of recording the fluctuation of corrosion rate, and can be hooked up to automatic monitoring and alarm systems.

Automated Control and Monitoring

Automated control allows cooling systems to adjust to changed conditions immediately, tending to maintain system stability and operating efficiency. The use of automatic monitoring and alarm systems, with or without automatic control, is also encouraged as these systems can alert operators to corrosive conditions and/or can maintain a continuous record of cooling system conditions. A continuous record of cooling system conditions can be useful in evaluating the performance of the cooling system and in diagnosing operating problems. Automation should be installed wherever possible.

Some of the possibilities for automatic control, monitoring and alarm include:

- Conductivity control of blowdown
- ORP control of chlorine, ozone, or chlorobromide action
- Chlorine residual control of chlorine dosage
- pH control of acid feed
- Turbidity control of sidestream filtration
- Corrosion rate monitoring and alarm

CLEANING AND PREFILMING OF COOLING SYSTEMS

Sometimes cooling systems are chemically cleaned and flushed to remove accumulated scale or biological fouling. The best way to protect against scaling and biological fouling is through the controlled use of conditioning chemicals as outlined above. However, if scale or biological growth build up excessively, cleaning and flushing may be necessary.

Cleaning agents should be non-acid type since acid cleaners can remove metals from the materials of construction of the cooling system. Many kinds of non-acid cleaners are available including chelating agents, polymers, and phosphates, or combinations of these.

It is important when cleaning a cooling system that polluted waters are not indiscriminately flushed into sanitary sewers. When cleaning and flushing a cooling system you should:

1. Test the cooling system waters before draining the cleaning fluids to make sure that the water does not exceed industrial waste discharge limits for copper, zinc, lead, and other toxics prior to dilution with other waste streams.

2. If the cooling water does not meet discharge limits it must be containerized in a portable on-site storage tank and hauled to off-site disposal, or treated before discharge to the sanitary sewer system.

Cleaning of fouled cooling systems should be done as a separate cleaning operation while the cooling system is off-line, rather than cleaning the cooling system by adding additional chemicals over a long period of time while the system is in normal operating mode (on-line cleaning). Off-line cleaning permits better control over the monitoring and disposal of cleaning wastes.

After cleaning, the cooling system should be given a prefilming treatment, as with phosphates or triazoles, to coat the metal surfaces with a protective layer. Do not use zinc-based compounds for prefilming.

Also, after your cooling system has been cleaned the corrosion inhibitors should be checked to make sure that protection is still adequate. Metal surfaces previously protected be scale may become exposed to the cooling water, providing increased area for corrosion to occur.

ADDITIONAL FACTORS

Water Treatment

Water treatment systems can be used either to reduce corrosion or to directly remove metals from the blowdown water. Since deposits can induce corrosion, sidestream filtration of particulates in the water may be desirable. Metal absorbing devices such as calcite filters or aluminum oxide filters can directly remove metals from blowdown water.

Sources of Makeup Water

The use of reclaimed water or recycled process waters is encouraged and should be investigated. Makeup water which has a high level of corrosion inducing elements (as compared to potable water) will require enhanced corrosion control and /or pretreatment. When switching to a new source to makeup water, be sure to re-evaluate and modify, as necessary, the corrosion control program.

Connections to the Wastewater Collection System

Cooling tower blowdown water should be periodically monitored to ensure that the industrial wastewater discharged from the facility conforms with Section 14 of the Revised Ordinance of Honolulu (ROH) 1990, as amended. Industrial wastewater discharges, which do not conform to the ROH, must be treated prior to discharging in the City and County of Honolulu (CCH) wastewater collection system. Discharging blowdown water from recycling cooling towers to the CCH storm drain system is permitted, provided the discharge is not a source of pollutants. However, a State of Hawaii NPDES permit and a CCH Department of Public Works (DPW) effluent discharge permit are required. Discharges from once-through cooling tower system may be discharged to the CCH storm drain system via a separate pipe. Facilities with once-through system, considering a storm drain discharge, should contact the DPW to verify if other restrictions apply. **PLANTER BOX DISCHARGES OF BLOWDOWN WATER DO NOT REQUIRE AN NPDES PERMIT.**

V. GETTING STARTED

1. Perform diagnostic tests and compare the results with the indicators in Table 1. Take corrective action if necessary.

2. Determine what conditioning chemicals the cooling system service company is using and make sure that chemicals containing copper, chromium, or zinc are not used.

3. Institute a regular monitoring and maintenance program.

4. When purchasing a new cooling system or replacing components, make sure that the materials purchased do not contain copper of zinc. Do not purchase non-recirculating ("Once through" or "single pass") cooling systems.

5. When initiating a new contract for servicing cooling systems, or when renewing an existing contract, specify in writing as many elements of these BMPs as possible so that the vendor must adhere to them.

VI. PENALTIES

Any person violating Articles 1 through 11 of the Revised Ordinance of Honolulu dealing with the CCH wastewater system could upon conviction be punished by a minimum fine of $1,000.00 per violation or by imprisonment not exceeding 90 days, or both. In cases where such offense shall continue after due notice, each day's continuance of the same shall constitute a separate offense. (Sec. 14-11.1, ROH 1990, AM.Ord.91-93) If you have any questions on this matter, please contact the Regulatory Control Branch at 692-5137.

FOR FURTHER REFERENCE

1. Betz Laboratories, Inc. Betz Handbook of Industrial Water Conditioning. Ninth Ed., 1991

2. Drew Chemical Corporation. Principles of Industrial Water Treatment. 1977.

3. Nalco Chemical Company. The NALCO Water Handbook. Second Edition. F.N. Kemmer, Ed. McGraw-Hill. 1988.

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